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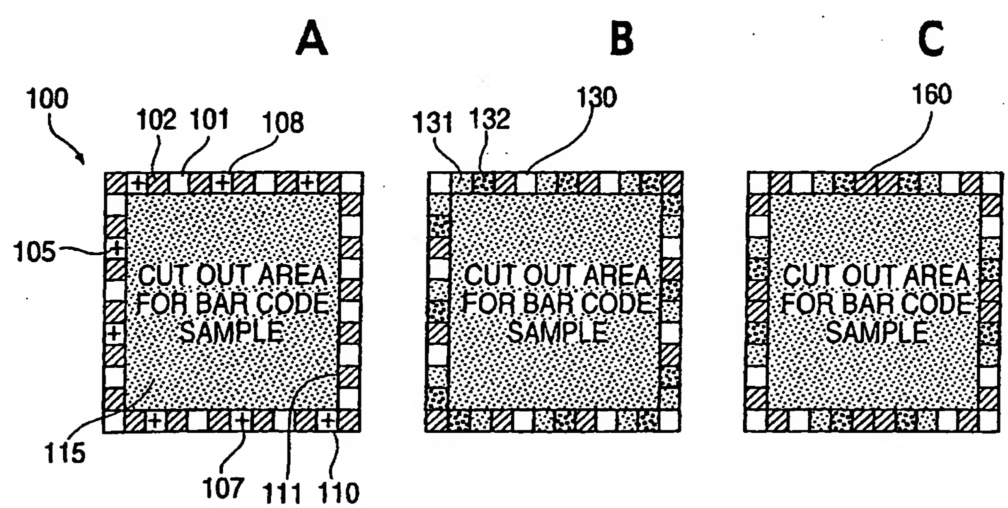


(57) Abstract: A method and apparatus for facilitating the calibration of verification devices used with encoded data symbols. The reflectance calibration tool includes a repeating pattern of black, white, gray, and/or other color shaded geometrical shapes that have been produced on a substrate. One or more of the shapes have spatial and reflectance characteristics that are traceable to known national or international standards. The geometrical shapes can include squares, rectangles, triangles, circles, or other polygonal structures arranged in a variety of patterns including square, rectangular, or circular patterns. The reflectance calibration tool can be produced in various shapes and sizes to meet the size, space, and/or resolution needs of (1) different sample bar code symbols; (2) the verifiers or imaging systems being used to analyze them; and (3) the methodology standards that are being followed for that measurement.

WO 00/77726 A1

METHOD AND APPARATUS FOR CALIBRATION OF AN IMAGE BASED VERIFICATION DEVICE

FIELD OF THE INVENTION

The present invention is directed to a method and apparatus for facilitating the calibration of verification devices used for verifying encoded data symbols. In particular, the present invention is directed to a reflectance calibration apparatus that can be used to calibrate the spatial and reflectance properties of a verifier to known national and international standards.

BACKGROUND OF THE INVENTION

Various types of symbol codes are used on merchandise, such as boxes, letters, packages, etc., for encoding pertinent information about the article of merchandise. In addition, many different automatic identification and data capture ("AIDC") techniques are currently being used to decode these encoded data symbols. These AIDC techniques are based on the ability to read or scan various encoded data or bar code symbols. These bar code symbols are typically based on upon a variety of symbologies, which are standardized and promulgated by various trade associations. For example, one dimensional ("1D") or linear bar code symbols are used commercially in many applications. These linear bar code symbols are useful in providing numeric and alpha-numeric information.

For example, product codes (also known as "bar code" symbols) are typically placed on an outer surface of the merchandise in order to encode information related to the merchandise in a point-of-sale transaction. An example of such encoded information would be the product identification number.

Based on the scanned bar code symbol, a memory can be accessed at the point-of-sale location to determine the cost of the scanned article of merchandise. This determination is based on the decoded bar code information that identifies the merchandise being sold. For example, based upon a decoded sequence of numbers

that correspond to the bar code on an article of merchandise, a lookup table storing the current price of the merchandise can be accessed.

Linear bar code symbols are well known. These types of bar code symbols are referred to as linear bar code symbols because they consist of a plurality of bars and spaces side by side. A linear bar code symbol is normally vertically redundant in that the same information is repeated regardless of the height of the bars and spaces. These 1D bar code symbols have been proliferated in a number of different standard symbologies such as UPC/EAN, Code 128, Code 39, etc. Trade associations, such as Automatic Identification Manufacturers ("AIM") have helped standardize the symbologies used in linear bar code symbols.

Linear bar code symbols typically lack the data density needed for storing detailed information concerning the object on which the code is affixed. For example, lines of a conventional bar code symbol can typically vary in a range from about 1/8" to 1" in height, and from about 10 to 52 mils in thickness. For most 1D bar code symbols, the spacings between the lines making up the bar code may be of various widths. The variations in the spacings are one element in determining the bar code characters making up the bar code symbol. Bar code information is read by illuminating the bars and spacings in a sequential manner. The bars absorb light and the background spacings reflect light. The pattern of these reflections and non-reflections is sensed by a bar code scanner.

The size and speed of modern conveyor systems, which carry packages of varying sizes with labels of encoded information affixed thereon, has created a need to utilize small, inexpensive and compact labels. A recent improvement to encoded data technology is the implementation of two dimensional ("2D") bar code symbols. 2D bar code symbols are based on a variety of symbologies that provide either stacked symbology or multi-row code, to name a few. 2D bar code symbols can utilize a coding technique where data/information is based on the position of black (or other color) spots or other geometric shapes within a matrix. Unlike vertically redundant

linear bar code symbols, 2D bar code symbols are multidimensional in that they store information along the height of the symbol as well as the length of the symbol.

United States Patent No. 4,998,010 describes one such encoded data labeling approach, using a large number of contiguous hexagons within a 1" x 1" area. Figure 1 shows a typical hexagonal coded symbol area 30, with a "bull's eye" center area 35 and a plurality of hexagons 20 placed at strategic locations outside of the bull's eye center area 35. The bull's eye is used as a locator. The bull's eye is also used for alignment purposes before the encoded information that corresponds to the hexagons 20 can be electro-optically scanned or imaged. Once a hexagonal-code scanner is aligned with the bull's eye pattern 35, the information corresponding to the plurality of hexagons 20 can be read.

Figure 1 also shows a maximum allowable area of the hexagonal coded symbol area 30, as given by lines 34H, 34V, and a minimum allowable area of the hexagonal coded symbol area 30, as given by lines 33H, 33V.

Figure 2 shows a blow-up of an area of the contiguous hexagons 20 that are make up part of the encoded information in the hexagonal coded symbol area 30. As can be seen from Figure 2, hexagonal shapes are well suited for encoding a large amount of information into a small area. The hexagons 20 fit within a "tiled array", with no wasted space between the hexagons 20. Referring back to Figure 1, the total area that the hexagonal coded symbol area 30 encompasses is approximately 1" x 1" (0.981" x 0.981" square using the minimum allowable space within lines 34H, 34V of Figure 1, 1.096" x 1.096" square using the maximum allowable space within lines 33H, 33V of Figure 1). The bull's eye center circle 44 typically is not located at the midpoint of the hexagonal coded symbol area 30.

Within the approximately 1" x 1" code symbol region, there is room for about 888 hexagons. Each of those 888 hexagonal areas is set to have either a black interior color (i.e, inked hexagon) or a white interior color (i.e., non-inked hexagon). This type of encoding allows a large amount of data to be encoded within

a very small area, and is well-suited for mail and package delivery services, which must accommodate packages and letters of all sizes. To be able to locate a package or letter through or during the delivery process, there is a need to encode information concerning how the package is to be delivered, whether the package is fragile and/or needs special handling requirements, whether the package needs to be kept in a special environment during shipping (e.g., temperature or humidity restrictions), etc.

A hexagonal encoding system such as that described above was developed by United Parcel Service (UPS), and is used extensively by UPS and others in determining the status of packages as they are sent from an origination location, through a series of intermediate locations, and finally on to a destination location. This encoding system is referred to as "MAXICODE" (originally "UPSCode"). Currently, there are over 20 different types of 2D symbologies available, including 3-DI, ArrayTag, and Aztec Code.

The reading or scanning of 2D bar code symbols presents greater difficulties than linear barcodes because two dimensions contain information instead of just one dimension. For example, matrix symbologies (which include a matrix of light and dark elements, circles, squares, or hexagons) require a vision based scanner to read the data. While 2D bar code symbols can be read by sweeping the horizontal beam of a hand held moving beam scanner down the 2D bar code symbol, this approach closely resembles the way a 1D bar code symbol is read. As a result, imaging devices, such as charge coupled devices ("CCDs") have become a preferable way to read 2D bar code symbols because the CCD can detect a full image of the 2D bar code symbol.

Another concern involving the use of 2D bar code symbols and 2D bar code symbol imagers is being able to verify the print quality of the 2D bar code symbol. Typically, if a bar code symbol reading/imaging system does not provide adequate or consistent results, it is usually because: (1) the scanner/system does not work properly; (2) the bar code symbol is defective; or (3) the database and/or correlation

to the 2D symbology is not correct. In scanning or reading a bar code symbol, it is necessary to meet a certain minimum quality level in the bar code symbol.

One way of ensuring a properly operating scanning system is by use of verification equipment. Under a conventional definition, verification is a process by which a bar code symbol is analyzed to determine if it has been printed in accordance with the print specifications of a particular bar code symbology and industry group against which the barcode was printed.

Verification equipment generally includes electro-optical and/or electro-optical-mechanical measuring devices that are used to test the reflectance and quality of printed bar code symbol. The verification devices are quality control devices that need to be calibrated to insure their measurements and responses agree with(or are at least correlated to) known, traceable National & International reflectance standards. Reflectance standards are available through laboratories and manufacturers certified by the National Institute of Standards and Technology ("NIST").

In the verification process, it is important to calibrate the measuring tool to some known standards. For example, conventional verification techniques and devices have been used to verify linear based bar code symbols. With a linear bar code verifier, data points are collected that represent reflectance values (i.e., the percentage of light reflected from the sample) and these values are used for the verification analysis. This process involves taking an analog signal of the reflectance and digitizing it, where the lowest value measured and the highest value measured are correlated to traceable reflectances. Usually the verification tool is in physical contact with the bar code being tested. Other types of non-contact verification techniques have been developed for linear bar code symbols, such as the technique described in U.S. Patent No. 5,504,315.

However, if one is using and testing a printed 2D bar code symbol, the conventional verification techniques will not be adequate. In order to determine a

"true" reflectance value, the reflectance value should be compared to a known reflectance value. Thus, image-based "print" quality verification of linear, stacked, matrix and multi-dimensional bar code symbols presents challenges in correlating the results of such analysis to known national and international standards for reflection and dimensional measurements.

SUMMARY OF THE INVENTION

In view of the foregoing, it would be desirable to provide an apparatus that can be used with an encoded data print quality verifier to facilitate calibration of the verifier.

The present invention provides a calibration apparatus for use with a verification device for encoded data symbols. The calibration apparatus includes a substrate having a first portion that includes a pattern of one or more geometric shapes. The pattern of one or more geometric shapes is arranged to be in proximity to an encoded data symbol within a field of view of the verification device. A reflectance value for one or more of the geometric shapes is traceable to a known standard.

In view of the foregoing, it would also be desirable to provide an imaging device for verification of an encoded data symbol, comprising a detector and a calibration tool. The calibration tool comprises a substrate having a first portion with a pattern of markings having at least one geometric shape. The pattern of markings is arranged proximate to an encoded data symbol within a field of view of said detector, where at least one geometric shape has a reflectance value traceable to a predetermined reflectance.

The present invention also provides a method of calibrating a verification device for encoded data symbols. A calibration tool is illuminated. The calibration tool includes a substrate having a first portion that includes a pattern of markings

having at least one geometric shape that are traceable to a known standard reflectance. An image of the calibration tool is then detected. The reflectance characteristics of the received image of the calibration tool are then correlated with a first set of known standards.

Further features and advantages of the invention, as well as the structure and operation of various embodiments of the invention, are described in detail below with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated herein and form part of the specification, illustrate the present invention and, together with the description, further serve to explain the principles of the invention and to enable a person skilled in the pertinent art to make and use the invention.

Figure 1 is a diagram of a conventional hexagonal code symbol with a bull's eye acquisition target located somewhere on the symbol.

Figure 2 is a diagram of part of the hexagonal honeycomb pattern that is used to encode information.

Figures 3A-3C show alternative embodiments of the reflectance calibration tool according to one embodiment of the invention.

Figure 4 shows a composite sample of an example reflectance calibration tool having a sample encoded data symbol in the central region of the calibration tool.

Figure 5 is an example verifier device implemented with a calibration program according to an embodiment of the invention.

Figure 6 is a front schematic view of the detecting head of the example verifier device.

Figure 7 shows a schematic view of the reflectance calibration tool of the invention being utilized with an example image capturing device.

Figure 8 is a flowchart of a calibration method according to an embodiment of the invention.

Figure 9 is a flowchart of an operational use of the calibration method according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The invention is directed to a method and apparatus for facilitating the calibration of verification devices used with encoded data symbols. In particular, the invention is directed to a method and apparatus for providing a reflectance calibration tool for calibrating a verifier of printed symbols that provide information in one or more dimensions. According to the invention, the reflectance calibration tool comprises a pattern of geometric shapes. In one embodiment, the reflectance calibration tool surrounds an encoded data symbol within the field of view of the verification device. In addition, the reflectance calibration tool can be used to test and correlate the reflectance levels within an existing verifier device. The method and apparatus of the present invention can be utilized with existing optical imaging equipment to provide calibration information that is traceable to a national or international standard.

As mentioned above, verification is useful in determining the quality of a printed symbol that represents some type of information. According to the invention, verification of encoded data symbols that provide data in one or more dimensions, such as 2D bar code symbols, can be achieved through use of a

reflectance calibration tool that provides repeatable and traceable results. By "traceable," it is meant that the result of the measurement can be related to some known national or international standards through an unbroken chain of comparisons. Accordingly, the reflectance calibration tool of the present invention provides both repeatability and traceability, so that the same sample always gives the same answers, even when using different verifiers.

When using verification equipment, a user is viewing images that are not only black and white, but that have gray levels in between the black and white. In addition, with encoded data symbols having data in more than one dimension, such as a 2D bar code symbol, a verifier must analyze the symbol's quality across an area, not just across a finite line. The verifier should have some way to measure an overall image and compare it to a standard value, while simultaneously ensuring that the image is evenly illuminated across the whole area. Thus if any variations in the reflectance are seen, the viewer will know that the variations are caused by the bar code symbol or variations in its printing, and not caused by the measuring device itself.

The present invention provides a reflectance calibration apparatus or tool for incorporating spatial, including linear and orthogonality, and reflectance calibration information together and around an image of an encoded data symbol. For calibrating a verifier capable of verifying any type of encoded data symbol (including 1D and 2D bar code symbols), the reflectance and spatial aspects of the verifier should be calibrated. For example, with matrix 2D bar code symbol verification, a user capturing a two dimensional image of the sample will obtain encoded information that is found in both the width and the height of the sample (as well as the positions within the matrix). Thus, for verification of a 2D bar code symbol to be of practical value, a verifier should be calibrated not only in reflectance, but also with respect to linear and axial uniformity aspects.

Briefly, the reflectance calibration tool or apparatus (referred to herein as the "reflectance calibration tool") comprises a pattern of black, white, and/or gray shaded

marks or markings having geometrical shapes that have been produced on a substrate. As used herein, substrate refers to any material of any shape on which the marks can be placed and detected. The shapes of the marks or markings can also be shaded with other colors, such as red, blue, or yellow. The geometrical shapes of the marks can include squares, rectangles, triangles, circles, or other polygonal structures. These shapes can be arranged in a variety of patterns including square, rectangular, circular, or semi-circular patterns. Rectangles or squares are preferable in that they correspond to the detecting element arrangements of most of the commercially available staring imagers and verifier systems. The substrate material which these shapes are printed on can be a transparent film, plastic, or glass, or an opaque material, such as metal. According to the present invention, the reflectance calibration tool can be produced in various shapes and sizes to meet the size, space, and resolution needs of (1) different sample bar code symbols; (2) the verifiers or imaging systems being used to analyze them; and (3) the methodology standards that are being followed for that measurement.

The reflectance calibration tool can be used to provide several different types of verification information, including linear positioning, distortion, and reflectance calibration. Example embodiments of the reflectance calibration tool are shown in Figs. 3A-3C. For example, in Fig. 3A, the pattern produced on the reflectance calibration tool 100 comprises an alternating pattern of markings having geometrical shapes, such as black squares 102 and white squares 101. According to the invention, one or more of these geometrical shapes is printed such that it has a predetermined reflectance value. In one embodiment, the reflectance value is traceable to a known national or international standard reflectance value. For example, NIST (as well as several international standards agencies) has a standard "white" and a standard "black." Several agency-approved laboratories and manufacturers, such as NIST-approved laboratories under the NVLAP accredited testing and calibration program, produce scales or "patches" which have a known reflectance that is traceable to the standard "whites" and "blacks" (and/or other colors) of the known NIST standards.

Preferably, although not necessarily, these shapes are equally spaced from each other around the outer portion or perimeter 110 of the substrate material. A sample bar code symbol can be placed in the central portion 115 of reflectance calibration tool 100 to create a composite sample. The composite sample can then be tested in an existing optical imaging device, such as a verifier that includes a bar code symbol imager or a page scanner. In one embodiment, the inner edge 111 of the perimeter pattern of shapes corresponds the outer edge of the sample bar code symbol.

Calibration of a verification device or system is achieved by use of known reflectance values corresponding to the different shapes printed on the reflectance calibration tool and the known dimensional and the predetermined positional aspects of the shapes within the tool (e.g., edge positions, grid lines, alignment marks, etc.). This calibration information can be used during an image analysis to better determine the overall reflectance and distortion characteristics of the bar code symbol under test. In the example of Fig. 3A, reflectance calibration tool 100 includes several white squares 107, 108 further having a cross-hair pattern within the square. The additional "reference marks" or reference points (such as cross-hairs, reference dots, etc.) can be added to the pattern of shapes to further enhance dimensional and distortion measurement capabilities.

Figs. 3A-C illustrate that there are several variations that can be used for the pattern of the reflectance calibration tool. For example, the tool could be utilized such that only the four corners of the image provide reflectance and/or spatial reference points. This pattern can inform the user that even illumination has been achieved. In addition, multiple gray scale levels can also be utilized on the reflectance calibration tool because the verifiers or imagers to be calibrated may or may not have linear responses. For example, Fig. 3B shows a reflectance calibration tool 130 having an alternating pattern of black, white, and gray squares. In this example, gray squares 131 and 132 correspond to two different intermediate gray shading levels. A reflectance calibration tool 160 having an alternative pattern of black, white and gray squares is shown in Fig. 3C.

Whether or not multiple shading levels are useful often depends on the verifier system that is being used. If a verifier system has a linear response, only two known values (e.g., a standard "black" and a standard "white") need be utilized. If the response is not linear, one or more gray patches, having a corresponding reflectance value somewhere between the black and white patches, can provide more accurate calibration results.

The reflectance calibration tool of the present invention can be placed either in contact with or in proximity to the bar code symbol to be tested. For example, as shown in Fig. 4, reflectance calibration tool 100 can comprise a pattern of alternating black and white squares disposed on a substrate material 125. If substrate material 125 is a solid film, plastic or metal, a 2D bar code symbol, such as the matrix based code symbol 202, can be placed in the central portion of the reflectance calibration tool. Alternatively, the reflectance calibration tool can have an opening corresponding to the central portion of the tool. In this embodiment, several different bar code symbols can be rapidly sampled without having to move the reference calibration tool. Thus, the perimeter pattern of shapes 110 can be coupled to the verifier without having to displace it in relation to the verifier's detecting elements.

An example verifier system implementing the reflectance calibration tool of the present invention is shown in Fig. 5. Verifier system 300 includes a main processor or computer 302, a calibration module 304, and a detecting head 306. Detecting head 306 is used to capture the image of a test sample 312. The test sample 312 is placed within the field of view 310 of the detecting head 306. Detecting head 306 includes one or more photosensitive detectors that receive light reflected off the test sample 312 and convert the received optical signal into an electrical signal. According to the present invention, the detecting head and processor can be either separate detached units or part of the same unit.

Preferably, test sample 312 is a composite sample that includes a reflectance calibration tool, such as calibration tool 100 from Fig. 3, and an encoded data symbol, such as a 2D bar code symbol discussed above. The electrical signal

corresponding to the image of test sample 312 is sent to computer 302 via conduit or cable 308. Cable 308 also can transport command signals from processor 302 to detecting head 306. Optionally, a support 314 can be utilized to fix the position of detecting head 306 in relation to test sample 312 to ensure consistent results from sample to sample. Support 314 can be used to keep detecting head 306 a predetermined fixed distance from test sample 312 so that the test sample is always kept in a known reference plane, preferably the image plane of detecting head 306.

Processor 302 can be a conventional personal computer having well known internal components that is implemented with calibration software, shown here as residing in calibration module 304, which performs the calibration functions discussed below. When the electrical signals corresponding to the image of the test sample are received by processor 302, the processor can perform a calibration analysis. The results of this analysis can be provided to a user via output 316. Preferably, output 316 is a graphical display, such as an LCD screen or conventional computer monitor, that provides graphical results to the user. In addition, a user interface (not shown) can be utilized to receive commands from the user to perform additional calibration analysis.

A more detailed view of the detecting head is shown in Fig. 6. According to one embodiment of the present invention, detecting head 306 includes an array of detecting elements 325. Optionally, detecting head 306 can further include one or more light sources 320 which are used to illuminate the test sample within the field of view 310 of the detecting elements 325 within the detecting head 306.

In a preferred embodiment, detecting elements 325 are arranged as in a conventional charge coupled device (CCD). A CCD is an array of photosensitive detectors which converts the reflected optical image into an electrical signal. CCDs are widely available, and include metal-oxide-semiconductor CCDs. CCDs are generally staring devices that produce a two dimensional picture of the image. Unlike conventional linear bar code symbol verifiers, a CCD can take a complete

"snapshot" of the image instead of having a single line trace across the bar code symbol.

In this embodiment of the present invention, the CCD detector uses a stationary flood of light from light sources 320 to uniformly illuminate test sample 312. As it is being illuminated, test sample 312 reflects a portion of the illumination back into the detecting head 306. Alternatively, ambient (or room) light can also be used to illuminate the test symbol.

For a verifier to provide accurate results, the illumination should be of a level sufficient to achieve the contrast needed to tell the difference between the colors, such as "black" and "white," of the composite test sample. In some cases, ambient light may provide a sufficient amount of light and contrast. However, most imaging situations are greatly improved by added light from additional sources. In some cases where the contrast of the test sample is low and/or the gain of the detector is also low, additional light illuminating the test sample is essential in providing sufficient contrast and differentiation for the detector/processor to perform accurate calibration analysis.

In a preferred embodiment, illumination can be achieved by positioning one or more light sources 320 (and their associated optics) on the verifier device itself. By using separate light sources, the lighting conditions and the illumination of the test symbol is controlled, rather than relying on ambient light alone. For example, light emitting diodes ("LEDs") can be utilized. LEDs are a preferable light source because they are compact, inexpensive, and widely available. Alternatively, lasers, such as diode lasers, or incoherent sources of light, such as lamps, can be also utilized according to the present invention. This fixed illumination system provides a consistent illumination reference value for each test sample imaged. Alternatively, the light source(s) can be detached from the image capturing device.

Light source(s) 320 can be used to illuminate the symbol under test at a variety of illumination wavelengths. For example, light sources can be utilized

which emit illumination at a particular wavelength, such as in the near infrared, in order to minimize the effects of ambient visible light on the test sample. In addition, filters, such as color or interference filters, can be placed in the reflectance path between the test sample and the detecting elements 325 to reduce the effects of ambient light entering the detecting head. Alternatively, the output intensity of light source(s) 320 can be great enough such that the relative amount of ambient light entering the detecting head 306 is reduced.

According to the present invention, calibration of a verification device can be achieved in a straightforward manner. Suppose that the printing quality of a 2D bar code symbol is to be verified and that the user desires to make sure that the verifier being used is properly calibrated. The reflectance calibration tool can be placed within the field of view of the detecting elements of the verifier. The reflectance calibration tool can be placed in relation to the sample bar code symbol such that the repeating geometric shapes of the outer portion of the reflectance calibration tool surround the sample bar code symbol.

Next, an image of the composite sample is taken by the verifier. In this one-step mode, the calibration routine can be performed to compare the captured image signal with the predetermined reflectance values associated with the reflectance calibration tool. As discussed above, these predetermined reflectance values are traceable to national or international standards.

For example, using tool 100 from Fig. 3A, if each "black" square represents two percent (2%) reflectance of the illumination, and each white square represents 98% reflectance, these values can be compared to the reflectance values stored at each pixel site viewing the image of those calibration squares on the detecting element of the detecting head. This information can be used to calibrate the verifier. If the test sample bar code symbol is also being imaged, this data can be used to compare the reflectance from the test sample to a traceable standard.

In addition, if reflectance calibration tool 100 is used (or some similar variation of it), which includes spatial reference points, then the captured image of the test symbol and calibration tool will provide spatial information with respect to the test symbol, which can further alert the user if there is any distortion of the printed test symbol.

Alternatively, a user could achieve similar results using a two step mode. First, an image of the reflectance calibration tool can be captured and stored in the memory of the computer. Second, a composite image of the reflectance calibration tool and the sample bar code symbol can be captured and stored in the memory of the computer. These two images can then be compared, and any differences existing in the reflectance values for the reflectance calibration tool can be normalized. Comparatively, the one-step mode provides calibration information and code information at the same time for comparison.

In addition to the embodiment shown in Figs. 5 and 6, a conventional 2D bar code symbol imaging system can also be suitable as a 2D bar code symbol quality control verification device. In this embodiment, the existing bar code symbol imaging device can be modified to include verification software. For example, as shown in Fig. 7, the detecting head 355 of a conventional 2D bar code symbol imaging system 350 can be used in combination with the reflectance calibration tool of the present invention. Detecting head 355 can include a CCD detecting element, such as the CCD described above.

According to one embodiment of the present invention, a reflectance calibration tool, such as calibration tool 100 from Fig. 3A, can be attached by a distancing piece (or extension holder) 360 on the detecting head 355. Extension holder 360 fixes the position of the reflectance calibration tool 100 within the field of view of the CCD. A sample bar code symbol can be placed in proximity to the central region of calibration tool 100. Thus, instead of just "reading" the sample bar code symbol, detecting head 355 can capture a composite image. Further, by using an extension holder, the reflectance calibration tool is always in the field of view of the

imager regardless of where the imager is placed in relation to the bar code symbol. Proper calibration software code, residing in calibration module 358, can be programmed onto the processor 356. By programming an existing bar code symbol imaging device with the verification methodology discussed herein, the imager device can function as a bar code symbol verifier or a print quality verifier. Alternatively, the captured composite image from detecting head 355 can be retrieved from the memory of imaging system 350 and processed on a separate computer implemented with the calibration software.

One of the advantages of the reflectance calibration tool of the present invention is that it can be implemented with existing optical imaging equipment to provide calibration information concerning a printed bar code symbol. According to one embodiment of the present invention, the reflectance calibration tool can be used in conjunction with a conventional page scanner to provide verification information.

A conventional page scanner, such as a Hewlett-Packard model HP ScanJet 5200C scanner, can be used to capture a composite image of the reflectance calibration tool and a test symbol. For example, a test symbol can be placed in the central region of the reflectance calibration tool. The combination can be placed on the scanning bed of a page scanner. As in scanning any printed document, a page scan process is then initiated where a scan line is moved across the combination. After the scanning is complete, a composite image can be stored as a gray-scale file (such as a "JPEG" or "TIFF" file) in the memory of the scanner. These files are based on reflectance values of the image.

The analysis can be performed using the stored data file that is transferred onto a computer implemented with the verification methodology described above. For example, the analysis program can have a set up menu that allows the user to select a prompt indicating that the verification analysis is to be performed on a gray scale file.

The stored image will comprise two components. First, the image will include a ring of dots (black, white, and/or gray) on the peripheral portion of the image corresponding to the pattern of the reflectance calibration tool. This first component corresponds to assigned reflectance values that are known. The second component corresponds to the central portion of the image, which has unknown reflectance values.

Once the stored image is loaded onto the processor or computer, a correlation can be performed comparing the known values to the unknown values. Thus, the reflectance calibration tool of the present invention can be utilized with existing optical imaging equipment to calibrate the image to known values in a straightforward manner.

The present invention also provides a method of calibrating a verification device. By properly calibrating a verifier, a user can be assured that the results of any printed encoded data symbol testing will be traceable to a known standard.

An example embodiment of a method of the present invention is shown in Fig. 8, which shows a flowchart of a calibration process 400 for calibrating a verifier. In step 402, a reflectance calibration tool that includes a pattern of geometric shapes that are arranged to surround an encoded data symbol is illuminated. In step 404, a composite image of the reflectance calibration tool and the encoded data symbol is detected. In step 406, the image detected in step 404 is correlated to known standards corresponding to the reflectance calibration tool. In step 410, the results of the correlation are outputted. These steps can be part of a software routine that is programmed on a conventional computer.

Optionally, calibration process 400 further includes determining the "true" reflectance values of the reflectance calibration tool (step 407). In addition, calibration process 400 can include determining the spatial alignment of the encoded data symbol being illuminated and detected (step 408). Calibration process 400 can further include measuring the distortion of the encoded data symbol (step 409).

Each of these steps can be performed as part of correlation step 406 or in separate subroutines.

With respect to step 402, the reflectance calibration tool can include any of the embodiments described above, such as the embodiments illustrated in Figs. 3A-3C. It is preferable that one or more of the shapes included in the reflectance calibration tool are traceable to known reflectance value(s). The illumination can be provided by ambient light or by a light source internal or external to a verifier. It is preferable that the light source has a controllable output intensity in order to provide more consistent results.

In addition, steps 402 and 404 can be modified so that a two-step mode is utilized. As mentioned above, in a two step mode, an image is first captured of the reflectance calibration tool. This image is then stored in the memory of a computer. Next, a composite image of the reflectance calibration tool and the encoded data symbol being tested is captured and stored in memory of the computer. Alternatively, an image of the encoded data symbol being tested is captured and stored in memory of the computer. These images can then be compared during correlation step 406. With respect to step 404, the image can be detected by a conventional verifier, page scanner, or modified imaging device, such as those described above.

By properly calibrating a verifier, several important aspects of the tested encoded data symbol can be verified. First, the evenness of the illumination of the image being captured can be determined. This calibration involves being able to determine whether illumination and reflection characteristics of the image are the result of the production and the use of the encoded data symbol and/or whether these characteristics are the result of the testing process and set-up. The calibration process also involves correlating the received illumination of the image's reflection characteristics to known standards provided by National or international authorities. For example, the reflectance calibration tool can be supplied by an accredited organization that is a traceable NIST laboratory. The supplier of the reflectance calibration tool would then provide the user with known values of size, shape and

reflectance. In the case of the calibration tool having a linear pattern, the supplier can provide the user with the exact spacings of the lines of the pattern. With the calibration information known to the user, that information can be applied to or programmed into the memory of the verification device or the processor used for performing the calibration routines. When the verifier captures an image of the encoded data symbol surrounded by the reflectance calibration tool, the image can then be compared to the "known" values that the image should possess.

According to one embodiment of the present invention, the received illumination of the image's spatial and reflection characteristics can be correlated to known standards. In a preferred embodiment, this correlation process can involve the determination of reflectance characteristics (step 407), spatial or linear alignment (step 408) and measurement of the image distortion and sizes of the image's characteristics (step 409) in conjunction with traceable national and international standards.

For example, correlation step 406 can be performed as follows. After the reflectance calibration tool is illuminated, the captured image of the reflectance calibration tool will correspond to a series of measured reflectance data points (corresponding to the number of pixels in the detector). Since the shape, spacing, and reflectance characteristics are provided by the supplier of the reflectance calibration tool, this traceable data can be stored in the processor or computer. Within the captured image, a predetermined portion of the measured reflectance data points represent the reflectance values from the reflectance calibration tool. These measured values are then compared to what the reflectance should be (e.g., corresponding to the specific reflectance calibration tool chosen initially). The results of this comparison are then used to calibrate or normalize the verifier.

If a composite image is taken, the measured reflected data points represent two sets of data: a first set corresponding to the known values for the reflectance calibration tool and a second set corresponding to "relative" size, shape, and reflectance values for the sample encoded data symbol. Because the verifier has imaged or scanned the reflectance calibration tool, the verifier can be calibrated so

that the measured shape and reflectance values are normalized to the corresponding known shape and reflectance values. This information is then compared to the "relative" shape and reflectance values measured for the sample encoded data symbol. The results of this comparison provide the user with meaningful and traceable information about the encoded data symbol being tested, in terms of reflection, spatial alignment, and distortion.

With respect to a distortion determination (step 409), the reflectance calibration tool initially chosen can have one or more spatial reference points, such as cross hairs, that establish a certain known distance. Such an example reflectance calibration tool is shown in Fig. 3A. If the distance between spatial reference points of the captured image of the reflectance calibration tool does not match the known predetermined distance, the measured difference value can be used to normalize the verifier. Thus, this distortion subroutine can inform the user that the sample encoded data symbol is of poor print quality (resulting in a distorted image).

In addition, the distortion subroutine can inform the user that there is a problem with the verifier or the test set-up. For example, referring back to Fig. 3A, suppose the reflectance calibration tool 100 includes a pattern of alternating black and white squares, with some white squares having cross-hairs. These cross-hairs establish reference points that provide known separation distances. Suppose cross-hair 107 is spaced exactly one inch from cross-hair 108. Calibration tool 100 is placed in the proper image plane of the verifier and an image is captured. If the measured spatial values for cross-hairs 107 and 108 do not correspond to a one inch separation distance, this discrepancy would alert the user that there is some distortion present in the verifier. This measured distortion is in the image because the shapes on the reflectance calibration tool should be spatially aligned to known values.

As mentioned above, the calibration process of the present invention can be implemented in a software routine to be run on a processor or personal computer. Fig. 9 shows a flowchart of a calibration program 450 that can be implemented on a

personal computer or processor. The precise code and user interfacing of the computer implemented with the calibration program can be varied according to user preferences as would be apparent to one skilled in the art given the present description.

In step 452, a verification calibration routine is chosen. The verification calibration routine can be any combination of the routines discussed above, such as a reflectance calibration of the verifier, a spatial calibration of the verifier, etc. In step 454, the user can input the specific reflectance calibration tool being used. Preferably, the spatial and reflectance information corresponding to one or more of the available reflectance calibration tools can be preprogrammed into memory of the computer when the calibration program is installed. In step 456, illumination information can be inputted or selected from a set of prompts to control the illumination characteristics of the test run. Alternatively, a default illumination setting can be provided in the program.

In step 458, an image is captured of the reflectance calibration tool. This step can be user initiated or automatically performed. A correlation program is performed in step 460. As discussed above, the correlation program compares the captured image of the reflectance calibration tool with the known spatial and/or reflectance values associated with the imaged calibration tool. Next, based on the results of the correlation program, the verifier can be calibrated in step 462. This calibration can be automatically performed or initiated by a user command. Any differences between the captured image values and the known values stored in the program can be used to automatically calibrate the verifier to traceable standards.

Thus, with the apparatus and method of the present invention, it is possible to calibrate the internal reflectance range of a print quality verifier by comparing relative values of measured data to known and traceable values, determine if there is linear or axial distortion of the measured image caused by the verifier's optical alignment (or caused by how the user is using it), and determine an actual linear

measurement (in terms of size and length) of the sample encoded data symbol and its components.

Conclusion

While the invention has been described in detail and with reference to specific embodiments thereof, it will be apparent to one skilled in the art that various changes and modifications can be made therein without departing from the spirit and scope of the invention. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

WHAT IS CLAIMED IS:

1. A calibration apparatus for use with a verification device for encoded data symbols, comprising:

a substrate having a first portion that includes a pattern of one or more geometric shapes, wherein said pattern of one or more geometric shapes is arranged to surround an encoded data symbol within a field of view of the verification device.

2. The calibration apparatus of claim 1, wherein a reflectance value for at least one of said geometric shapes is traceable to a known standard.

3. The calibration apparatus of claim 2, wherein said substrate is selected from the group consisting of films, glasses, plastics, and metals.

4. The calibration apparatus of claim 2, wherein said pattern of one or more geometric shapes comprises an alternating pattern of equally spaced black and white shapes.

5. The calibration apparatus of claim 4, wherein said pattern of one or more geometric shapes further comprises one or more reference marks for providing distance reference points on said calibration apparatus.

6. The calibration apparatus of claim 2, wherein said pattern of one or more geometric shapes comprises an alternating pattern of equally spaced black, gray, and white shapes.

7. An imaging device for verification of an encoded data symbol, comprising:

a detector; and

a calibration tool, said calibration tool comprising a substrate having a first portion with a pattern of markings having at least one geometric shape, said pattern of markings arranged proximate to an encoded data symbol within a field of view of said detector, said at least one geometric shape having a reflectance value traceable to a predetermined reflectance.

8. The imaging device of claim 7, wherein said detector comprises a charge coupled device (CCD) that includes an array of pixels for receiving an image of the encoded data symbol.

9. The imaging device of claim 8, further comprising:

an extension mountable on said detector for holding said verification tool at a predetermined distance from said array of pixels.

10. The imaging device of claim 7, further comprising:

a processor coupled to said detector to receive an electronic signal corresponding to an image of the calibration tool and the encoded data symbol.

11. The imaging device of claim 10, further comprising:

a computer useable medium having computer program logic recorded thereon for enabling said processor to calibrate the imaging device, said computer program logic including means for enabling the processor to correlate reflectance values of said image of the calibration tool to a predetermined value.

12. The imaging device of claim 11, wherein said computer program logic further includes means for enabling said processor to determine a spatial alignment of said encoded data symbol.

13. The imaging device of claim 11, wherein said computer program logic further includes means for enabling said processor to measure a distortion of an image of said encoded data symbol.

14. The imaging device of claim 7, wherein said predetermined reflectance is a known standard reflectance.

15. A method of calibrating a verification device for encoded data symbols, comprising:

illuminating a calibration tool that includes a substrate having a first portion that includes a pattern of markings having at least one geometric shape, said at least one geometric shape having a reflectance value that is traceable to a standard reflectance;

detecting an image of said calibration tool; and

correlating reflectance characteristics of a received image of said calibration tool with a first set of known standards.

16. The method of claim 15, wherein said of markings having at least one geometric shape is proximate to an encoded data symbol within a field of view of a detector, wherein said detecting step comprises:

detecting an image of said calibration tool and said encoded data symbol.

17. The method of claim 16, further comprising:

determining a spatial alignment of said encoded data symbol.

18. The method of claim 16, further comprising:

measuring a distortion of an image of said encoded data symbol.

19. The method of claim 15, further comprising:

automatically calibrating the detector based on a result of said correlation.

20. The method of claim 15, further comprising:

providing an output based on said correlation.

21. A computer program product comprising a computer useable medium having computer program logic recorded thereon for enabling a processor to calibrate the imaging device, said computer program logic comprising:

means for enabling the processor to receive an image of a calibration tool that includes a substrate having a first portion that includes a pattern of markings having at least one geometric shape, wherein said pattern of markings having at least one geometric shape is arranged proximate to an encoded data symbol within a field

of view of a detector, said at least one geometric shape having a reflectance value that is traceable to a standard reflectance; and

means for enabling the processor to correlate reflectance characteristics of said received image of said calibration tool with a first set of known standards.

22. The computer program product of claim 21, said computer logic further comprising:

means for enabling the processor to determine a spatial alignment of said encoded data symbol; and

means for enabling the processor to measure a distortion of an image of said encoded data symbol.

23. A calibration apparatus for use with a verification device for encoded data symbols, comprising:

a substrate having a first portion with a pattern of markings having at least one geometric shape, said pattern of markings arranged proximate to an encoded data symbol within a field of view of the verification device.

24. The calibration apparatus of claim 23, wherein a reflectance value for said at least one geometric shape is traceable to a known standard.

25. The calibration apparatus of claim 24, wherein said substrate is selected from the group consisting of films, glasses, plastics, and metals.

26. The calibration apparatus of claim 24, wherein said pattern of markings comprises an alternating pattern of equally spaced black and white marks.

27. The calibration apparatus of claim 26, wherein said pattern of markings further comprises one or more reference marks for providing distance reference points on said calibration apparatus.

28. The calibration apparatus of claim 24, wherein said pattern of markings comprises an alternating pattern of equally spaced black, gray, and white markings.

FIG. 1

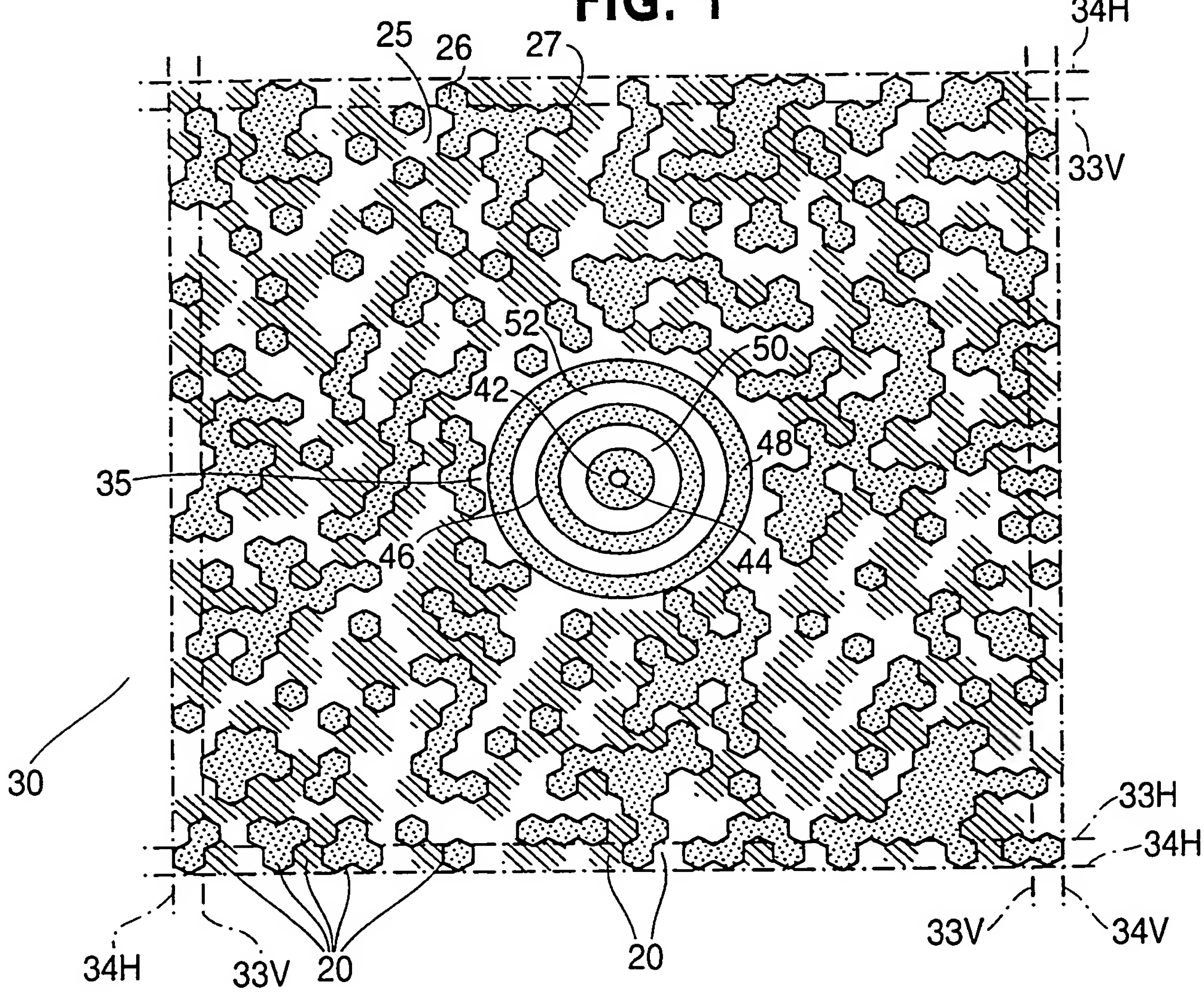
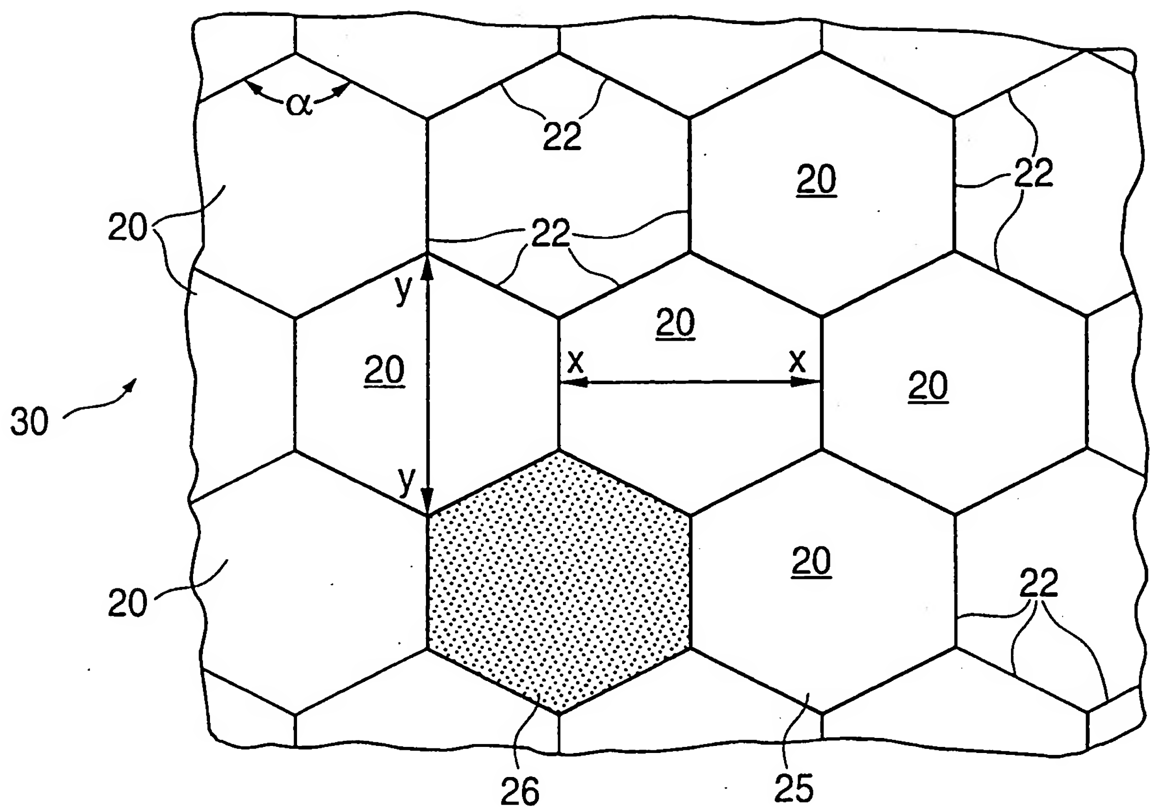

34H
25
26
27
33V
52
50
42
48
35
46
44
30
33H
34H
34H
33V
20
20
33V
34V

FIG. 2



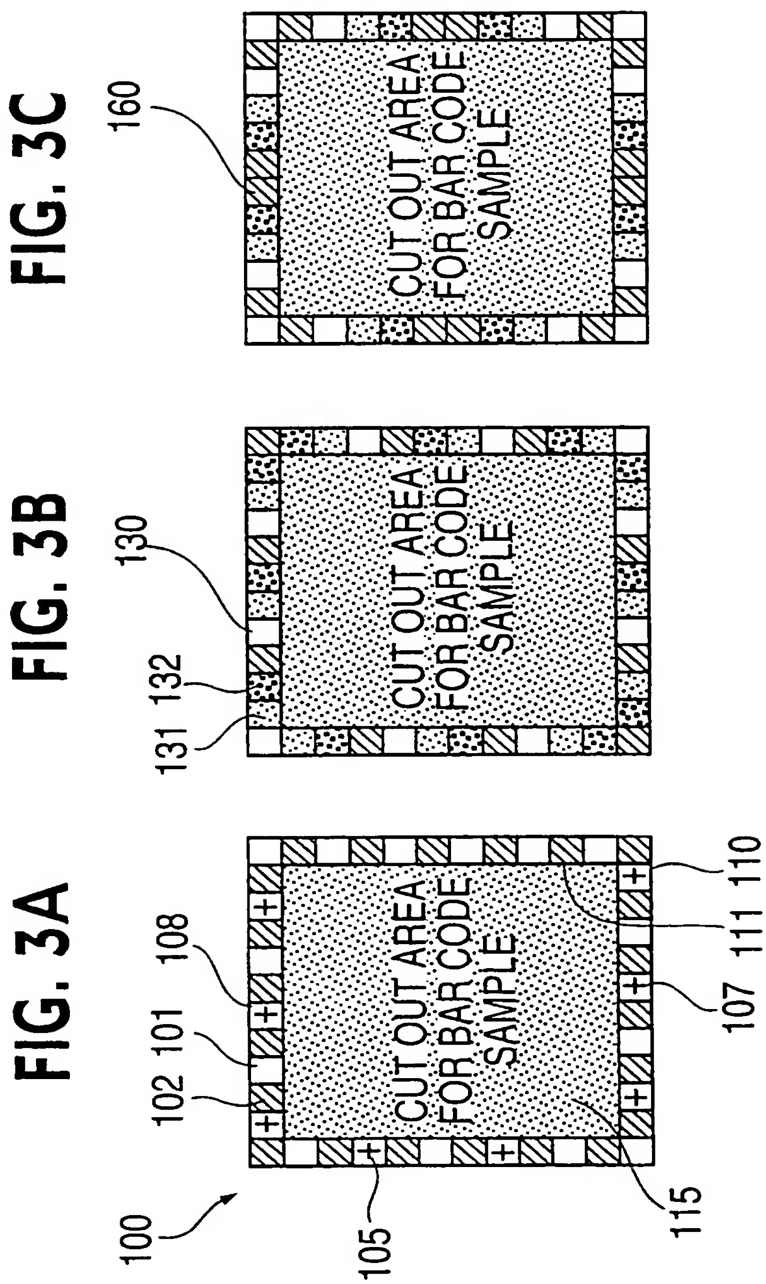


FIG. 3A
FIG. 3B
FIG. 3C
CUT OUT AREA
FOR BAR CODE
SAMPLE
100
101
102
105
107
108
110
111
115
130
131
132
160

FIG. 4

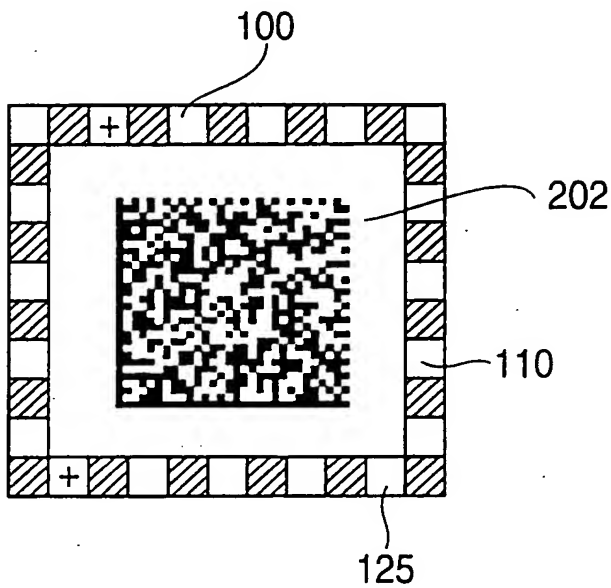


FIG. 5

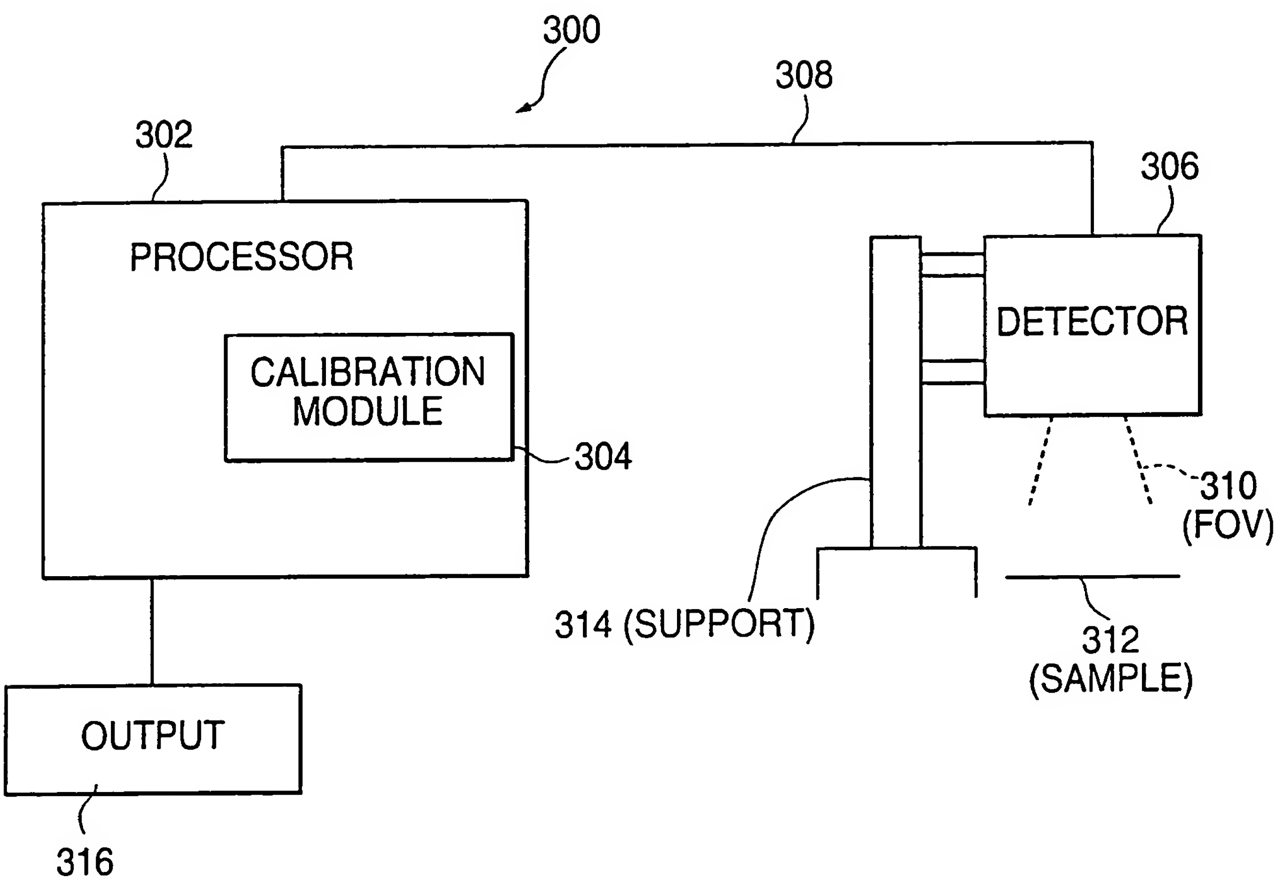

300
308
302
306
PROCESSOR
CALIBRATION
MODULE
DETECTOR
304
310
(FOV)
314 (SUPPORT)
312
(SAMPLE)
OUTPUT
316

FIG. 6

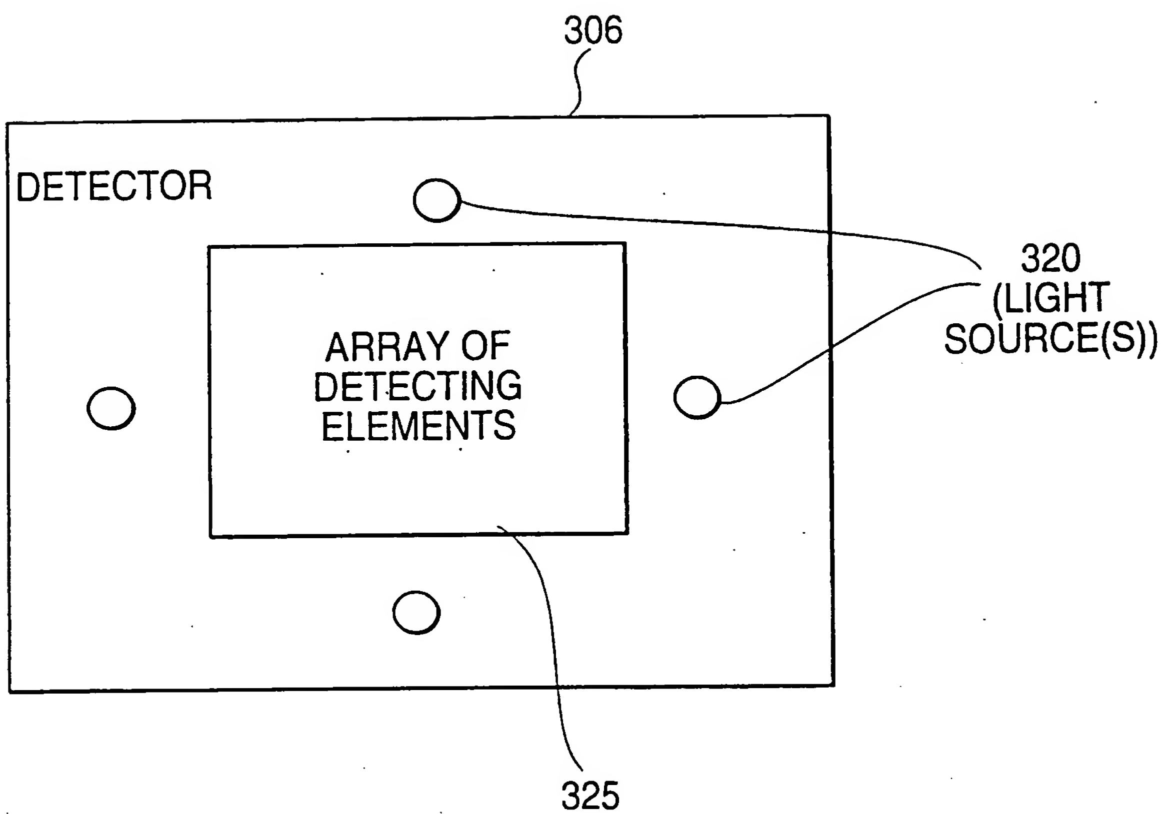

306
DETECTOR
ARRAY OF
DETECTING
ELEMENTS
320
(LIGHT
SOURCE(S))
325

FIG.7

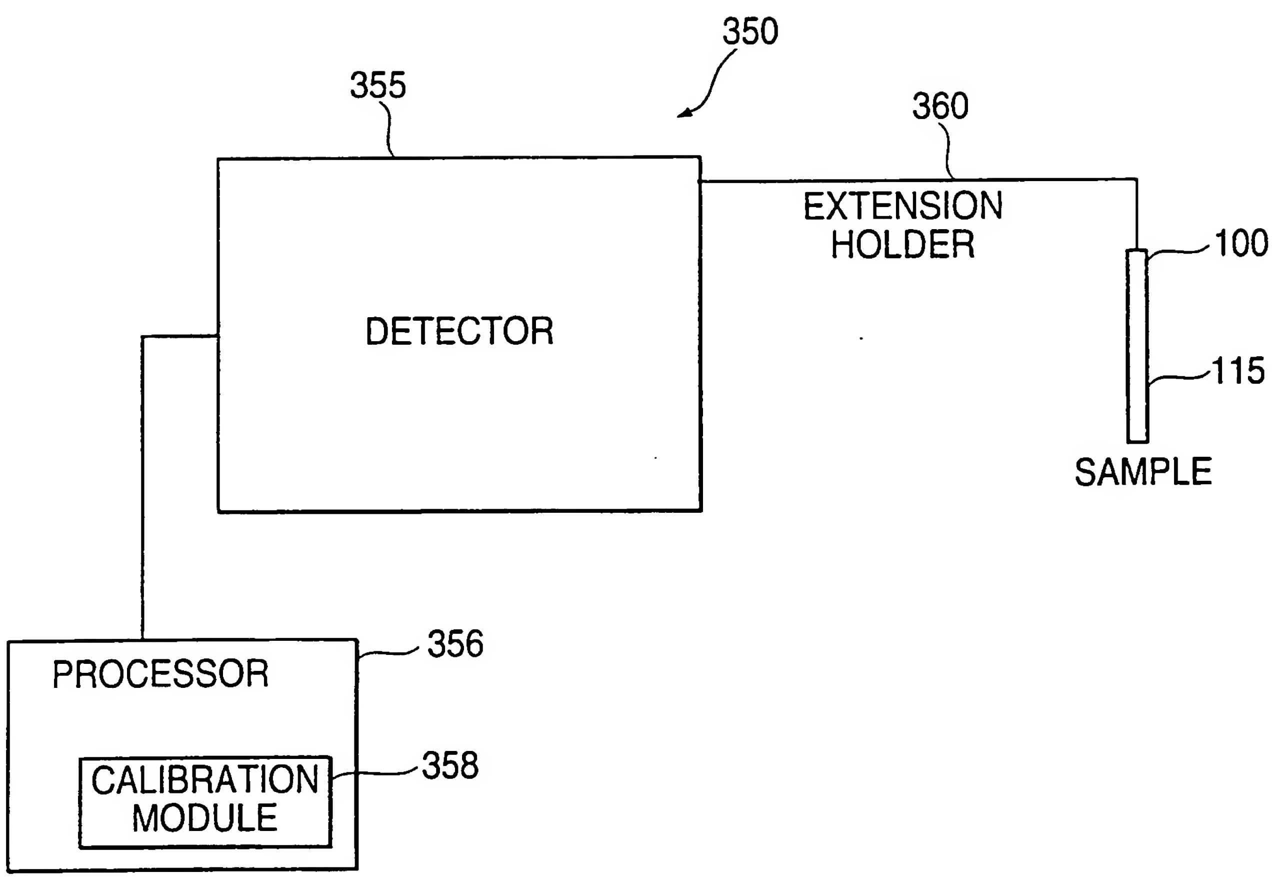

350
355
360
EXTENSION
HOLDER
100
DETECTOR
115
SAMPLE
PROCESSOR
356
CALIBRATION
MODULE
358

FIG. 8

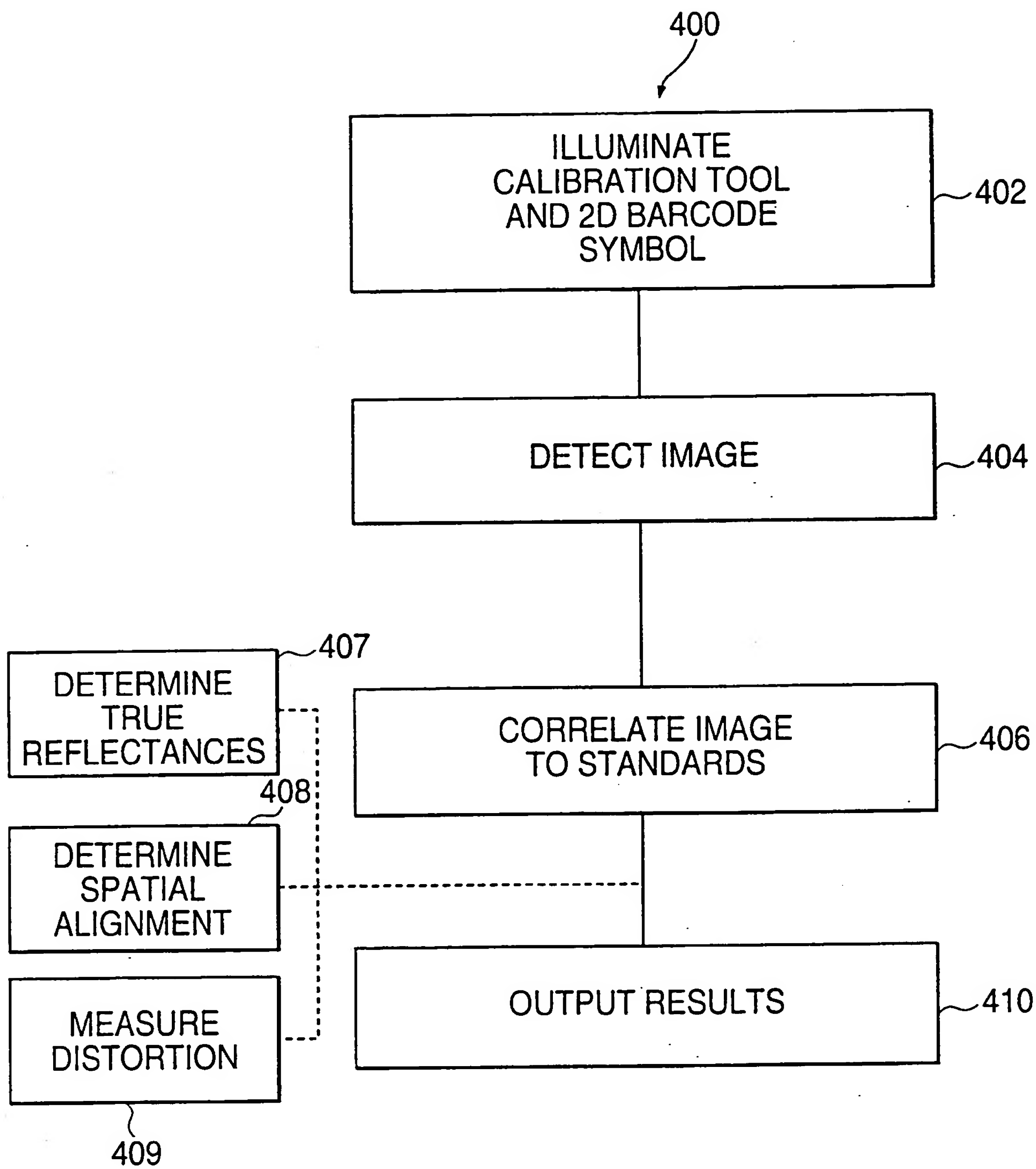
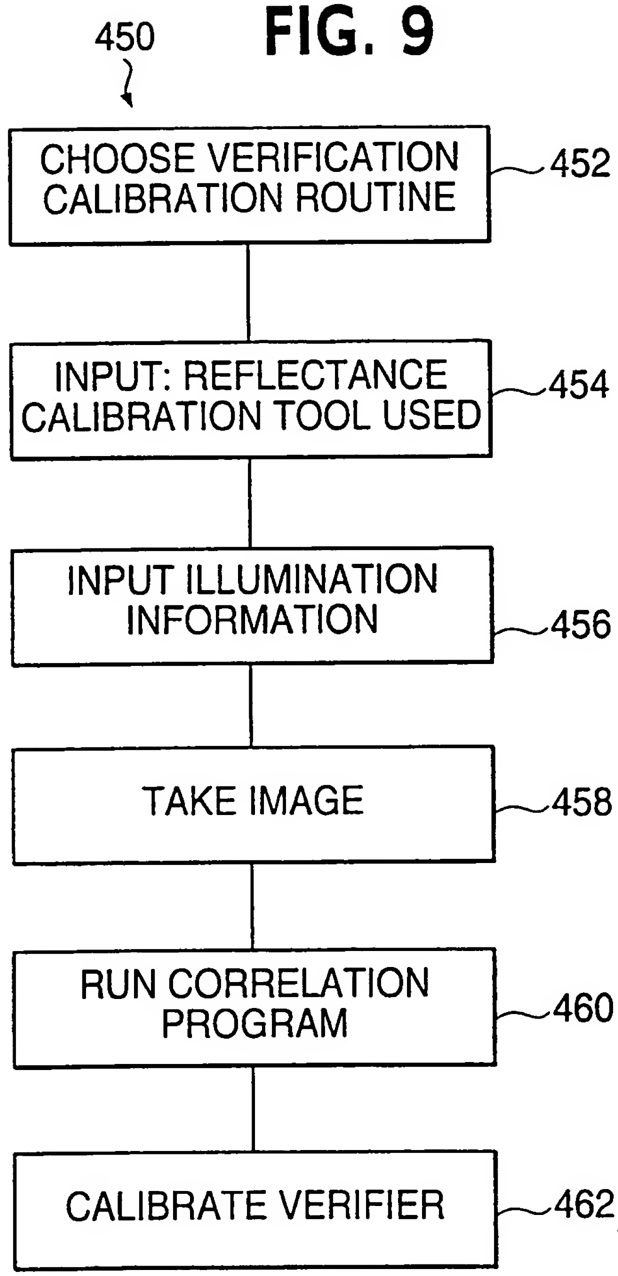

400
ILLUMINATE CALIBRATION TOOL AND 2D BARCODE SYMBOL
402
DETECT IMAGE
404
DETERMINE TRUE REFLECTANCES
407
CORRELATE IMAGE TO STANDARDS
406
408
DETERMINE SPATIAL ALIGNMENT
MEASURE DISTORTION
OUTPUT RESULTS
410
409

FIG. 9


450
CHOOSE VERIFICATION CALIBRATION ROUTINE
452
INPUT: REFLECTANCE CALIBRATION TOOL USED
454
INPUT ILLUMINATION INFORMATION
456
TAKE IMAGE
458
RUN CORRELATION PROGRAM
460
CALIBRATE VERIFIER
462

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/16604

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06K19/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 5 541 396 A (RENTSCH FREDERIC) 30 July 1996 (1996-07-30) column 2, line 38 - line 63 column 3, line 58 -column 4, line 51 column 11, line 21 -column 12, line 25 column 12, line 42 - line 56	1-5,7,8, 10-27 6,9
X	US 5 818 032 A (SUN TSU-HUNG TOM ET AL) 6 October 1998 (1998-10-06) column 10, line 42 -column 11, line 35	1,2,5,7, 8,10, 14-24,27
A	US 3 998 556 A (WRIGHT ROBERT V) 21 December 1976 (1976-12-21) column 1, line 59 -column 3, line 11	1,7,15, 21,23

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 October 2000	10/10/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Goossens, A

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INTERNATIONAL SEARCH REPORT

Information on patent family members

onal Application No
PCT/US 00/16604

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 5541396	A	30-07-1996	AT	174142	T	15-12-1998
			AU	668095	B	26-04-1996
			AU	2326492	A	23-02-1993
			CA	2091269	A	20-01-1993
			DE	69227755	D	14-01-1999
			WO	9302429	A	04-02-1993
			EP	0549765	A	07-07-1993
			JP	6502036	T	03-03-1994
US 5818032	A	06-10-1998	NONE			
US 3998556	A	21-12-1976	NONE			